

AD-A188 227 APPLICATIONS OF SATELLITE METEOROLOGY IN SUPPORT OF
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PATRICK AFB FL B B BOYD ET AL. DEC 86 ESMC-TR-86-07
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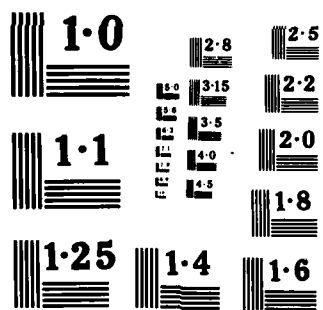
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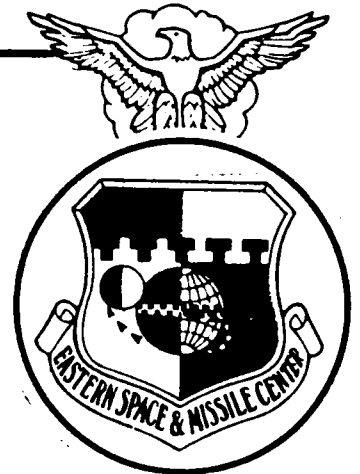
ESMC-TR-85-07

APPLICATIONS OF SATELLITE METEOROLOGY IN SUPPORT
OF SPACE SHUTTLE OPERATIONS

B.F. BOYD
T.M. MYERS, MAJOR USAF
Eastern Space and Missile Center
Patrick Air Force Base, Fla 32925

31 December 1985

FINAL REPORT



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AD-A166 227

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED		1b. RESTRICTIVE MARKINGS NONE										
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.										
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE												
4. PERFORMING ORGANIZATION REPORT NUMBER(S) ESMC-TR-85-07		5. MONITORING ORGANIZATION REPORT NUMBER(S)										
6a. NAME OF PERFORMING ORGANIZATION Eastern Space and Missile Center	6b. OFFICE SYMBOL (If applicable) ESMC/WE	7a. NAME OF MONITORING ORGANIZATION										
6c. ADDRESS (City, State and ZIP Code) Patrick Air Force Base FLA 32925		7b. ADDRESS (City, State and ZIP Code)										
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER										
8c. ADDRESS (City, State and ZIP Code)		10. SOURCE OF FUNDING NOS. <table border="1"><tr><td>PROGRAM ELEMENT NO.</td><td>PROJECT NO.</td><td>TASK NO.</td><td>WORK UNIT NO.</td></tr><tr><td></td><td></td><td></td><td></td></tr></table>		PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.					
PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.									
11. TITLE (Include Security Classification) Applications of Satellite Meteorology in Support of Space Shuttle												
12. PERSONAL AUTHOR(S) Operations. Boyd, B. B.; Myers, T. M., and Funk, C. S.												
13a. TYPE OF REPORT Technical	13b. TIME COVERED FROM 1981 TO 1985	14. DATE OF REPORT (Yr., Mo., Day) 1985, December	15. PAGE COUNT 6									
16. SUPPLEMENTARY NOTATION												
17. COSATI CODES <table border="1"><tr><td>FIELD</td><td>GROUP</td><td>SUB. GR.</td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr></table>		FIELD	GROUP	SUB. GR.							18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Meteorology, Weather, Shuttle, Satellite, Interactive Graphics	
FIELD	GROUP	SUB. GR.										
19. ABSTRACT (Continue on reverse if necessary and identify by block number) The paper presents a background on Shuttle operations and their sensitivities to weather. It lists an overview of weather impacts to the Shuttle operations 1981-1985. A brief summary of recent uses of the Meteorological Interactive Data Display System is presented with one specific mission (61A, 30 October 1985) described in detail.												
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input checked="" type="checkbox"/> DTIC USERS <input type="checkbox"/>		21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED										
22a. NAME OF RESPONSIBLE INDIVIDUAL BILLIE F. BOYD		22b. TELEPHONE NUMBER (Include Area Code) 305-494-5915	22c. OFFICE SYMBOL ESMC/WER									

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APPLICATIONS OF SATELLITE METEOROLOGY IN
SUPPORT OF SPACE SHUTTLE OPERATIONS

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B. F. Boyd, T. M. Myers, and C. S. Funk

Office of the Staff Meteorologist
Eastern Space and Missile Center
Patrick Air Force Base, Florida

1. INTRODUCTION

The United States Air Force (USAF) Air Weather Service's Detachment 11 of the 2nd Weather Squadron is tasked to provide meteorological and environmental support to the USAF Eastern Space and Missile Center (ESMC), the National Aeronautics and Space Administration's (NASA) Kennedy Space Center (KSC), and the Department of Defense (DOD) Manager for Space Shuttle Support Operations. They provide weather support to the Cape Canaveral Air Force Station (CCAFS), Patrick Air Force Base (PAFB), KSC, and the entire Eastern Test Range (ETR); primarily through the Cape Canaveral Forecast Facility (CCFF). The CCFF is a 24-hour-a-day forecasting and observing operation. As part of its normal support, it provides specialized forecasts for all missile and space launches from the ETR/KSC and weather services for recovery forces. By far, the launch, landing, and ground operations of the Space Shuttle require the most precise weather support. Most aspects of Space Shuttle operations are sensitive to one or more meteorological parameters. As the Shuttle proved itself in its early missions (Table 1) and became operational with a significant increase in the number of scheduled missions (Table 2), it was evident that weather and weather support would become critical elements in achieving and maintaining the higher launch rate.

TABLE 1

SHUTTLES LAUNCHED BY YEAR

YEAR	TOTAL LAUNCHED
1981	2
1982	3
1983	4
1984	5
1985	9

TABLE 2

PROJECTED SHUTTLE LAUNCHES BY YEAR

YEAR	TOTAL LAUNCHES
1986	17
1987	23
1988	24

To deal with this problem, NASA and the USAF, at the local level, formed a joint Meteorological Systems Modernization Program (MSMP). This group is co-chaired by the Technology Projects Office of the KSC and the Office of the Staff Meteorologist of the ESMC. Through the efforts of the MSMP, and joint funding by the Air Force and NASA, several improvements in meteorological systems were accomplished, allowing better utilization of satellite data. The key improvement was the Meteorological Interactive Data Display System (MIDDS).

2. THE METEOROLOGICAL INTERACTIVE DATA DISPLAY SYSTEM (MIDDS)

To assist the forecaster with the problems of integrating data from various sources and producing mission support products which use all of the available data in an internally consistent manner, the MIDDS was developed under contract with the Space and Science Engineering Center (SSEC). The MIDDS (Young, 1985) consists of an IBM 4341 computer with appropriate peripherals and workstations in supporting a variation of the Man Computer Interactive Data Access System (McIDAS) software (Suoni, 1983). The system provides integration of the data sources available to the CCFF into a single data base where the various types of data can be melded and displayed together for forecaster use. It also provides growth for new data sources and allows for a significant increase in the applications which the forecasters and system users are expected to make after they become more familiar with the power of the system. Utilization of the MIDDS over an eighteen month period has been presented previously by Kolczynski, Myers, and Boyd (1985,

1986, 1986). To better understand weather impacts to the Shuttle, one must look at Shuttle operations and weather constraints,

3. SHUTTLE OPERATIONS

There are many aspects to Shuttle operations that are much more susceptible to weather than the casual observer might realize,

3.1 Launch and Landing.

The relative low frequency of flight might lead one to think the most optimal times for launch as related to weather are easily attained. Just the opposite is true. Actual launch times are rigidly controlled by the orbital mechanics of the particular payloads and to some extent with other orbiting vehicles. In the extreme case, mission 51-G had only a four minute launch window. Although most missions are not that restrictive, all have fairly limited launch periods. Within those limited launch windows there may be a much smaller optimal launch period. Once launch is accomplished, Return To Launch Site (RTLS) and Transatlantic Abort (TAL) landings are also fixed. Abort Once Around (AOA) and normal End of Mission (EOM) are somewhat more flexible, but those opportunities are also very restrictive at any given site, with normally not more than two opportunities per day. For a launch to be completed, weather for a RTLS must also be acceptable. The climatological chances for a successful launch vary at the ETR by time of day and month as illustrated by Figures 1 and 2.

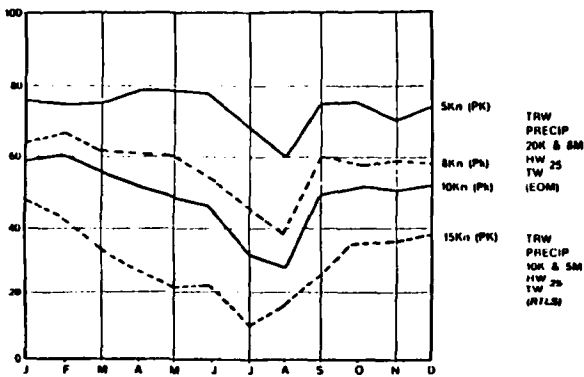


Fig. 1. Percent Probability No Go All Parameters 0800L.

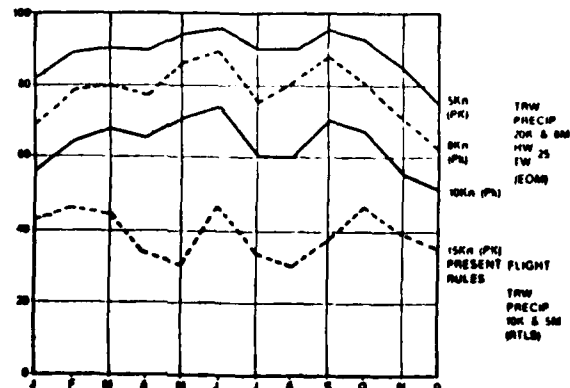


Fig. 2. Percent Probability No Go all Parameters 1400L.

3.2 Prelaunch Processing.

Although launch and landings are the most visible Shuttle operations, there is much to be accomplished between flights. When a payload is returned from outer space aboard the orbiter, the vehicle is towed back along the tow road to one of the Orbiter Processing Facilities (OPFs). In the OPF the payloads are removed, the payload bay is reconfigured for the next mission, broken tiles are repaired, brakes are fixed, etc. Once the orbiter is ready, it is towed to the Vehicle Assembly Building (VAB) where it is put in an upright position and stacked on top of the Mobile Launch Platform where it is mated with the Solid Rocket Boosters (SRBs) and the External Tank (ET). Once this process is complete the entire Mobile Launch Platform is transported along the crawlerway 4.1 miles to Launch Complex 39A, typically a 6 to 8 hour trip during which the vehicle is vulnerable to weather. The Mobile Launch Platform, along with the vehicle, is left on the pad after the crawler pulls out from underneath it. The vehicle is launched from the Mobile Launch Platform. Any loss of production during this processing cycle may well impact launches when the number of processing days are condensed due to more frequent launches. The single largest loss of processing time is due to thunderstorms. Loss of production time due to lightning occurrences has been a problem since the origin of the space program at the ETR. (Gibbons, et al, 1985)

4. SHUTTLE WEATHER CONSTRAINTS

As shown in Table 3, weather impacts nearly all facets of Shuttle operations from rollover and rollout to final recovery of the Shuttle at end of mission. This table clearly illustrates the sensitivity of Shuttle operations to the environment and the subsequent impact of forecast support in maintaining Shuttle launch schedules.

TABLE 3

STS WEATHER SENSITIVITIES

Temperature, Winds, Precipitation

Temperature less than 31°F or greater than 99°F.

Precipitation forecast or occurring from the start of external tank loading through launch.

Ice accumulation greater than 1/16 inch on the external tank.

Surface winds (measured at 60 feet above natural grade) greater than 34.4 knots (peak) or 22.6 knots (steady state) from all azimuths (lift off).

Prelaunch surface winds greater than 49 knots steady state while on the pad.

Upper air wind shears outside vehicle load limits.

Flightpath (Nominal or RTLS)
Severe Weather Constraints
(to protect the vehicle from lightning strikes)

Cannot be within 2NM above or 5NM horizontal distance of the anvil associated with a thunderstorm.

Cannot be through any cloud (convective or layered) from which precipitation (including virga) is observed.

Cannot be through clouds in the dissipating stage which have detected lightning by the electric field mill network within 15 minutes prior to launch.

Cannot be through any cloud if a 1000 volt per meter or greater ground level electric field contour encompasses launch (or landing) site.

Offshore Crew Recovery Area Constraints
(from launch pad to 50NM in the Atlantic)

Surface wind greater than 25 knots.

Ceiling less than 500 feet.

Visibility less than 0.5NM.

Seas greater than 8 feet.

Solid Rocket Booster (SRB)
Recovery Area Constraints

Sea state greater than sea state code 3 (3-5 foot moderate waves).

Visibility less than 1.5NM.

Landing Constraints
(Return to Launch Site and End of Mission)

Ceiling less than 10,000 feet (8,000 feet if Microwave Landing System (MLS) available).

Visibility less than 7 miles (5 miles if MLS). Final launch decision relies on slant range evaluation by weather reconnaissance flights along the return to launch site path at KSC and reentry profile at Edwards AFB or White Sands.

Surface wind component (including max gusts) greater than 25 knots headwind, 20 knots crosswind (lakebed), 15 knots crosswind (runway), 10 knots crosswind (EOM), or 10 knots tailwind.

Any precipitation (RTLS), or precipitation within 50NM (EOM at KSC).

Turbulence greater than light to moderate.

Range Safety Constraints

The ESMC Office of Range Safety also has restrictions under the following weather conditions, due to tracking and blast damage considerations:

Ceiling less than 1,600 feet.

Visibility less than 5 miles.

Blast due to destruct sequence resulting in predicted fatality probability values greater than one per-hundred thousand will result in hold or scrub.

Shuttle Ferry Flight
(Edwards AFB to KSC)

If the Shuttle lands at Edwards AFB instead of the Kennedy Space Center, the following weather constraints apply to the return flight of the NASA B-747 Shuttle Carrier Aircraft:

Flight conducted daylight hours only.

No flight through visible moisture.

Flight level temperature must be greater than 15°F.

No turbulence greater than moderate.

Crosswinds must be less than 15 knots for takeoff and landing.

Take off runway ambient air temperature must be less than 92°F.

5. A CASE STUDY

Weather has impacted the Shuttle in various ways over the history of the program. A general overview is contained in Table 4.

TABLE 4

WEATHER IMPACT
(THROUGH DEC 85)

<u>MISSION</u>	<u>IMPACT</u>
STS-3	EOM diverted to WSSII and delayed 1 day (Mar 82)
STS-7	EOM diverted to Edwards vice KSC (Jun 83)
STS-8	Launch delayed 17 minutes by thundershowers (Aug 83)
41-C	EOM diverted to Edwards due to KSC weather (Apr 84)
41-D	SCA flight delayed 1 day due to tropical storm Diana (Aug 84)
51-A	Launch delayed 1 day by windshears (Nov 84)
51-C	Delayed due to cold temperature impacts on ET fueling (Jan 85)
51-D	Held to end of launch window by clouds and showers (Apr 85)
51-D	Landing delayed 1 orbit due to showers. Landed with maximum crosswind at KSC (Apr 85)
SCA	Orbiter Columbia TPS damaged by precipitation during transit to KSC

61-C Weather (clouds) hold to near end of window, then aborted due to vehicle problem (Dec 85)

A recent case where the use of satellite data via the MIDDS prevented a weather impact was mission 61A, 30 October 1985. Tropical Storm Juan had dominated the weather along the Gulf states and Florida for several days prior to launch, requiring a detailed metwatch during prelaunch processing as well as the launch itself. In the 48 hours prior to launch a number of operations occurred which are weather sensitive such as: loading of the external tank, last minute payload work, and work along the exposed service structures. Forecasters at the Cape Canaveral Forecast Facility (CCFF), using the MIDDS looping capability of GOES imagery and incorporating wind tower and lightning detection data were able to minimize the impact of the transient squall line feeder bands of Tropical Storm Juan resulting in a nominal launch countdown. Figures 3 thru 6 show daily accumulated rainfall for the southeast, and the eastward movement along the Gulf coast of the rainfall maximum through 30 October (NOAA, 1985). Figures 7 and 8 show the 1200 GMT position of Juan on 30 October.

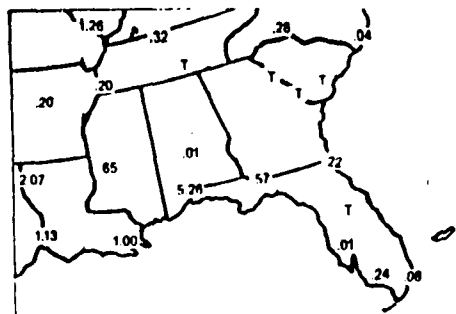


Fig. 6. 24 Hour Precipitation Totals for 31 Oct 85.

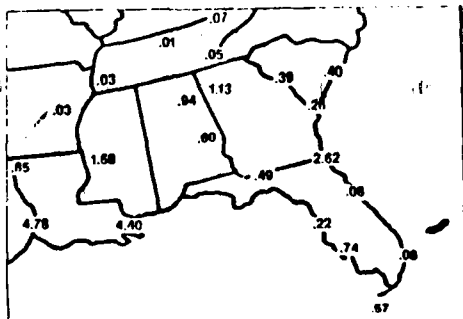


Fig. 3. 24 Hour Precipitation Totals for 28 Oct 85.

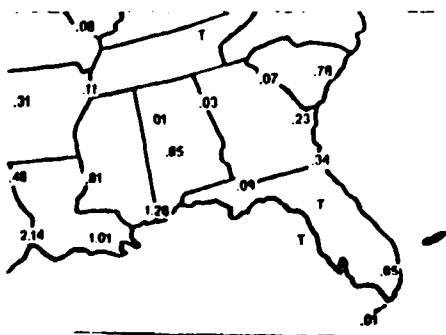


Fig. 4. 24 Hour Precipitation Totals for 29 Oct 85.

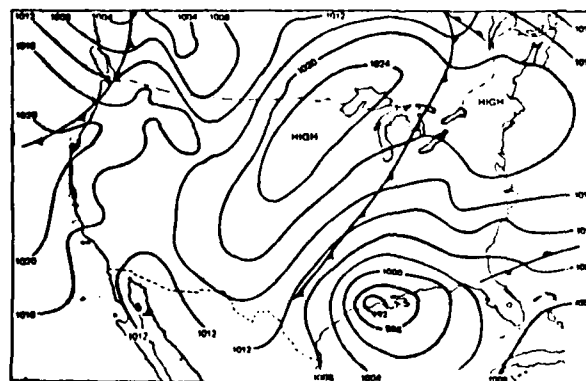


Fig. 7. Surface Weather Map at 0700 EST, 30 Oct 85.

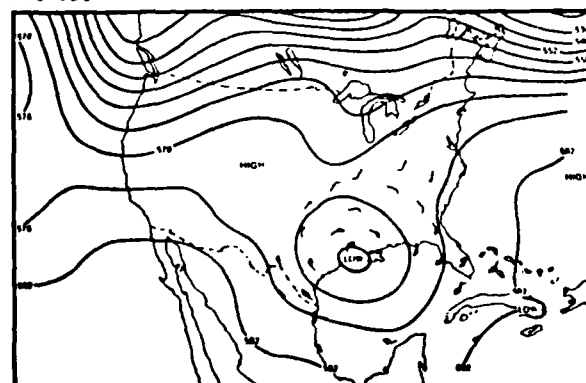


Fig. 8. 500-Millibar Height Contours at 7:00 A.M., 30 Oct 85.

5.2. Mission 61A Weather Support.

At the launch minus 24 (-24) hours briefing, through utilization of the MIDDS graphic analysis and image looping, the Shuttle Weather Officer (SWO) was able to assure the launch control officials that the only direct impact of Tropical Storm Juan would be in the form of the squall line feeder bands. On launch day, the local weather situation was further complicated by a weak frontal boundary approaching north Florida and forecast temperatures in excess of 80°F contributing to the already unstable environment. At launch -8 hours the launch director was briefed of the possibility of intermittent rainshowers and thunderstorms during the launch window (1700-2000 GMT). Looking at the most current near realtime satellite imagery on the closed circuit television system and forecast guidance by the Shuttle weather forecasters, the launch director made the decision to load the external tanks and begin final preparations for launch. As the launch countdown progressed a squall line in the Gulf of Mexico off the west coast of Florida presented an area of particular concern. After sunrise, clear skies over most of central Florida allowed rapid warming of the land surface and the convective process began. By 1600 GMT (11 AM EST) the squall line was along the west coast of Florida (see Figure 9 for clouds as depicted by the MIDDS).

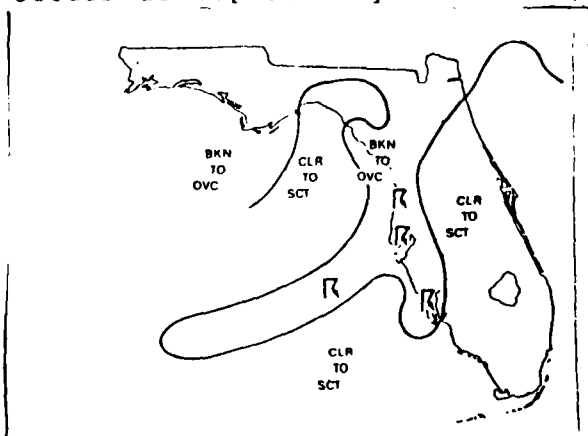


Fig. 9. Cloud Depiction 16Z, 30 Oct 85.

Numerous thundershowers and rainshowers accompanied the feeder band. Cumulus and towering cumulus were developing throughout east Florida and the launch area. At launch -45 minutes, a conference was held between the launch director, flight director, mission management team, and the SWO at the CCF for launch weather and the Spaceflight Meteorology Group in Houston for TAL and AOA weather. The SWO, using the available GOES rapid scan data, displayed the developing thunderstorm pattern and cumulus fields. He discussed the threat of thunderstorm development along outflow boundaries in the unstable local environment and suggested a Go as early in the launch window as possible. As the 1700 GMT opening of the launch window approached, so did the thunderstorms. At 1700 GMT on 30 October, (Figure 10), STS 61-A was launched successfully from pad 39A at the Kennedy Space Center. According to the official

NASA release, despite a tropical storm threatening the Gulf coast states and Florida for several days, the "countdown was uneventful and ascent to orbit normal".

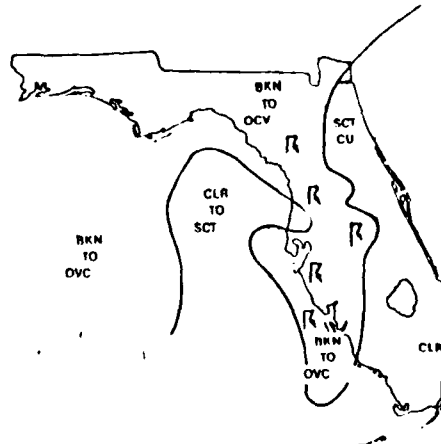


Fig. 10. Cloud Depiction 17Z, 30 Oct 85.

6. SUMMARY

This paper has presented a background to Shuttle operations and their sensitivities to the weather. A brief overview of weather impacts was presented to establish the impacts, and one specific mission application used as an illustration of typical satellite applications to Shuttle missions. The MIDDS and its readily available satellite data are key elements of weather support essential to the successful Shuttle operations.

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